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PILOT-SCALE STUDY ON BATAC JIG WASHING OF COARSE REFUSE - WESTAR COAL LTD.

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PILOT-SCALE STUDY ON BATAC JIG WASHING OF COARSE REFUSE - WESTAR COAL LTD.

by

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ABSTRACT

A 15 tonne coarse refuse sample was submitted by Westar Coal Ltd. for pilot plant Batac jig evaluation for the plus 0.6 mm and, water-only-cyclone (WOC) and froth flotation for the minus 0.6 mm. The objectives of the program were to produce clean coal for thermal use with 27912 kJ/kg heat value and outline a flowsheet to achieve it.

The coarse refuse was crushed to minus 12.7 mm and showed significant improvement in coal washability as reflected on increased recovery from 32.5 to 44% by mass at 20.8% ash (27912 kJ/kg). Overall average results of the Batac jig indicate probable error of 0.16 at 1.58 cutpoint. Projection from the washing tests using the Batac jig for 12.7 x 0.6 mm shows a thermal recovery of approximately 61.6% can be achieved to produce clean coal with 20.8% ash (db). Both water-only-cyclone (WOC) and froth flotation performed well and resulted in clean coal with 13.9% ash for the WOC and 9.5 to 17.6% ash for the froth flotation depending on rate of reagent used.

Based on coarse refuse characteristics and pilot plant testing, a flowsheet is proposed to clean the plus 0.5 mm in a Batac jig or heavy medium cyclone and, WOC and froth flotation for the minus 0.5 mm. Based on projection from pilot plant testing results, the proposed flowsheet is expected to produce clean coal with 27900 kJ/kg (similar to foothills thermal coal with approximately 12% ash) with minimum recovery of 39.7% by mass which corresponds to 63.0% thermal recovery.

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ÉTUDE À L'ÉCHELLE-PILOTE DU LAVAGE SUR CRIBLE BATAC D'UN CHARBON DE REBUT GROSSIER PRÉSENTÉ PAR LA WESTAR COAL LTD.

par

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RÉSUMÉ

Un échantillon constitué de 15 tonnes de charbon de rebut grossier a été présenté par la Westar Coal Ltd. pour fins d'évaluation à l'échelle-pilote sur crible Batac des fractions de plus de 0,6 mm, et des fractions de moins 0,6 mm à l'aide d'un cyclone à eau seulement (WOG) et de la flottation par moussage. Le programme visait la production d'un charbon épuré ayant un pouvoir calorifique de 27 912 kJ/kg, destiné à des utilisations thermiques et l'élaboration d'un schéma de principe illustrant le mode opératoire.

Les rebuts grossiers ont été broyés à une dimension de moins 12,7 mm. La lavabilité du charbon s'est grandement améliorée, ce qui s'est traduit par une augmentation du taux de récupération qui est passé de 32,5 à 44 % (massique), avec une teneur en cendre de 20,8 % (27 912 kJ/kg). Dans l'ensemble, la moyenne des résultats découlant de l'évaluation sur crible Batac indique une erreur probale de 0,6, à un point de coupe de 1,58. Les prévisions concernant les essais d'épuration des fractions 12,7 X 0,6 mm au moyen du crible Batac, démontrent que le pouvoir calorifique peut atteindre environ 61,6 % ce qui permet d'obtenir un charbon épuré ayant une teneur en cendre de 20,8 % (db). Le cyclone à eau seulement (WOC) et la flottation par moussage ont donné de bons résultats et permis d'obtenir un charbon contenant 13,9 % et 9,5 à 17,6 % de cendre, respectivement, selon la vitesse du réactif employé.

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En se fondant sur les caractéristiques du charbon de rebut grossier et sur les résultats de l'essai à l'échelle-pilote, on propose d'élaborer un schéma de principe en vue d'épurer les fractions de plus de 0,5 mm sur crible Batac, et les fractions de moins de 0,5 mm, à l'aide d'un cyclone à eau seulement et de la flottation par moussage. Selon les prévisions découlant des résultats obtenus suite aux essais à l'échelle-pilote, on s'attend à ce que le schéma de principe proposé permette d'obtenir un charbon épuré de 27 900 kJ/kg (semblable au charbon thermique des Foothills de l'Alberta dont la teneur en cendre est d'environ 12 %), avec un taux de récupération de 39,7 % (massique) ce qui correspond à un pouvoir calorifique de 63,0 % .

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INTRODUCTION

A pilot plant scale Batac jig was recently installed at the Coal Research Laboratory (CRL) pilot plant facilities in Edmonton. The Batac jig project is partly financed by several coal companies to evaluate the Batac jig in washing their coals. The project is intended to generate test data and experience on Canadian coals to reduce risks in designing new plants and in modifying existing ones.

In Germany, use of the Batac jig in washing both coarse and fine fractions is common in newly designed plants and is gradually replacing the heavy medium bath in existing plants. The common practice is to use the jig to wash the coarse (plus 10 mm) and fine (10 x 0.5 mm) fractions separately. The increased application of the Batac jig both in Germany and other countries is claimed to be due to the following advantages (1):

1. large tonnages can be treated, simplify plant size and layout and reduce capital cost
2. because of its precise controls, the jig is able to respond quickly to changes either in feed rates or in coal characteristics
3. estimated operating cost is 40% less than for heavy medium systems
4. performance compares favourably with heavy medium systems for cutpoints above 1.55 for coals with limited amounts of near density material.

Generally Canadian coals are not as easy to wash as German coals. The Batac jig offers certain advantages, but an understanding of how it behaves with Canadian coals is not clear. The testing program on different Canadian coals can benefit industry by verifying reported claims and generating data for commercial plant design.

A bulk sample weighing approximately 15 tonnes was collected from the coarse refuse stock pile and delivered to the CRL. This report presents results and discussions of washing tests, evaluates and compares the Batac jig performance with other systems, and discusses the feasibility of recovering saleable coal from refuse dumps to meet required objectives.

COAL CHARACTERISTICS

The bulk sample was a coarse refuse from washed bituminous coal. The analysis given in Table 1 is carried on a split of the bulk sample (approx. 15 tonne) and considered representative of the bulk sample received for the washing tests.

SIZE DISTRIBUTION

The sample received was coarse with 7.3% by mass as minus 0.6 mm size. The bulk sample was crushed to minus 12.7 mm and the screen analysis is shown in Table 2. Crushing increased the minus 0.6 mm to 19.6% by mass. The analyses indicate a trend similar to most western Canadian coals, i.e. ash contents decrease with decrease in particle size since relatively low ash particles tend to be more friable than those higher in ash. Table 2 indicates that the plus 12.7 mm fraction can be removed by screening and rejected as refuse with 65.1% ash.

HEAT VALUE/ASH CONTENT

The thermal content can be reliably expressed as a linear functon of the ash content of a given coal. The ash and thermal contents of different densities and size fractions are used to establish the following relationship (Appendix A).

$$kJ/kg(db) = 36372 - 406.2 * Ash$$

where ash is expressed in per cent.

A minimum heat value of 27912 kJ/kg (12000 Btu/lb) is required for the clean coal product (comparable in heat value to Foothills clean coal with 12% ash). This corresponds to 20.8% ash (db) and equivalent to 20.7% ash as received basis (0.6% moisture a.r.b.).

WASHABILITY

Washability analyses were carried out on two fractions with top size ranges of 100 mm (as received) and 12.7 mm (100 mm crushed to minus 12.7 mm). The coarse size range washabilities (minus 100 mm) would represent the coarse refuse as mined from refuse dumps. The crushed minus 12.7 mm washabilities represent the coarse refuse being fed to the pilot

plant and also considered as possible size for future recovery of saleable coal after washing.

Washability curves of the 100 x 0.6 mm in Fig. 1 (data in Table 3) indicate a theoretical recovery of 32.5% by mass at 1.59 cutpoint (dp) with 20.8% ash (27912 kJ/kg). For the 0.6 x 0.25 mm fraction, washability data (Table 4 and Fig. 2) indicate relatively higher theoretical recovery of 75% by mass at 1.97 dp with 20.8% ash. This difference is common in coal waste dumps and is due to the fact that at the time of processing, the coarse coal particles (plus 0.6 mm) were more effectively separated from the refuse than were the fines particles. Washability data for the 0.25 mm x 0 are shown in Table 5. Washability curves of the 12.7 x 0.6 mm and 0.6 x 0.15 mm (after reducing the top size from 100 to 12.7 mm) indicate changes in coal washability that reflect an increased recovery due to liberation in middlings particles (Fig. 3 and 4, Tables 6 and 7).

The overall effect of crushing the refuse from 100 mm to 12.7 is examined. Figure 5 indicates significant improvement in coal washability as a result of crushing. The improvement is reflected in an increased recovery of 11.5% by mass (from 32.5 to 44% in Fig. 5). As a result, it is beneficial to crush the coarse refuse to 12.7 mm top size to liberate coal particles from middlings particles and to generate new surface (unoxidized) for fine particles that would respond favourably to froth flotation.

COAL FLOATABILITY

Flotation tests are carried out on the minus 0.2 mm size fraction using a standard Denver laboratory flotation machine. A number of reagents are used in different rates and proportions. The results shown in Table 8 indicate good recovery of froth, however, at relatively high ash contents (19 - 30%).

PERFORMANCE PREDICTION

In practice, actual recoveries are lower than the theoretical recoveries because of errors of separation inherent in any process. The effect of these errors of separation can be seen from the predicted results of washing in Figure 6 for the plus 0.6 mm. These predictions cover the dp range of 1.40 to 1.80 relative densities. The probable error (r) is a parameter used in prediction calculations to convert the theoretical results

(from washability curves) into the practical results which one could expect from the actual process. The prediction curves include heavy medium cyclone (HMC), Baum jig and water-only-cyclone (WOC). These predictions are necessary to determine pilot plant flowsheet and setting of equipment parameters to achieve the cleaning objectives. From the curves, it appears likely in practice that a washed coal with 20.8% ash (27912 kJ/kg) would be obtained with thermal recovery of 70.8, 60.7 and 50.6 per cent in kJ (calculated from Fig. 6: clean coal thermal value x mass recovery/raw coal thermal value) for HMC, Baum jig and WOC with corresponding dp's of 1.66, 1.57 and 1.53 respectively.

WASHING TESTS

The processing of Westar refuse sample at the Fuel Processing Laboratory pilot plant facilities included feed preparation, two cleaning circuits, dewatering and water treatment. A detailed description of the 10 tonne/hr pilot plant facility has been reported earlier (2) and a simplified flowsheet is shown in figure 7. The following is a brief outline of the pilot plant circuits.

Feed Preparation

The raw coal is prepared to a 12.7 mm top size by screening out the minus 10 mm coal and recombining it with the plus 10 mm fraction which has been crushed in a hammer mill.

Cleaning

a) Coarse coal circuit: The bulk raw coal slurry 12.7 mm x 0 has the minus 0.5 mm fraction removed before processing in a Batac jig. The Batac jig produces a reject product, a middlings (which is recirculated) and a coarse clean coal product.

b) Fine coal circuit: The minus 0.5 mm fraction which was removed before coarse coal cleaning is processed in a two stage 200 mm diameter water-only cyclone. After screening, the minus 0.15 mm fraction is processed in a bank of 6 Denver flotation cells.

Dewatering

The coarse and fine clean coal fractions are combined and dewatered together in a pusher-type centrifuge. The thickener underflow or fine reject is dewatered in a solid bowl centrifuge while the coarse reject is dewatered over a 0.6 mm vibrating screen.

Water treatment

Process water containing flotation tailings and secondary compound water cyclone underflow is treated in a bottom fed thickener to produce clarified water for recirculation. The thickened fine reject is then dewatered in a solid bowl centrifuge.

TEST PROCEDURE

The objective of the pilot plant washing tests was to evaluate the performance of the Batac jig to recover coal (12.7 x 0.6 mm) from crushed coarse refuse, producing clean coal with an ash content ranging between 17 and 22%. Optimum thermal recovery was the main criterion in setting the separation cutpoints of both the smalls (12.7 x 0.6 mm) and the fines (minus 0.6 mm) cleaning circuits. A total of six tests (open circuit) were run with some changes in dp settings.

After the initial adjustment of the jig and cyclones settings, short preliminary run was made and samples collected for analysis to determine if further adjustment of the equipment was required. Incremental samples were taken of the raw coal, clean coal and reject products for all tests. The end products and also some of the intermediate products of the long runs were collected to evaluate the overall performance of the plant and determine material balance.

The ash and moisture contents of the samples were determined following each test run. Screen and float-sink analyses of samples of the main runs were carried out by the Birtley Engineering Laboratory in Calgary along with attrition tests.

DISCUSSION OF RESULTS

A total of approximately 14 tonne of coarse refuse with 47.4% ash was washed in the pilot plant. The average of two tests produced a clean coal yield of 22.49% with 12.7 to 19.5% ash clean coal. Average thermal recovery was 37.8%. A summary of these two tests and some other test runs are shown in Tables 9 and 10. Higher dp than 1.6 for the coarse (plus 0.6 mm) and fines (minus 0.6 mm) would improve the thermal recovery, however at higher ash level than 19% in the clean coal.

PLANT PERFORMANCE

Plant performance is defined by the probable error (r) which reflects the sharpness of separation at a given cutpoint (dp). These parameters are derived from the distribution curve. The distribution curve is a plot of the percentage of the feed to a washing unit that reports as refuse versus the relative density. The cutpoint (dp) is defined as the relative density at which 50% of the feed reports to refuse and 50% to product. The probable error (r) for a distribution curve is one half the difference of the relative density interval at the ordinates of 25 and 75 per cent and this is a measure of the slope of the middle portion of the distribution curve. The better the separation, the steeper the slope of this curve and the smaller the probable error.

Batac Jig Performance

Table 11 shows the summary of two Batac jig tests performance (two size fractions for each) for dp between 1.4 and 1.60. Error curves related to the two size ranges of 12.7 x 2 mm and 2 x 0.6 mm fraction are shown in Fig. 8 and a composite in Fig. 9. As can be expected dp and r (Table 11) increased with decrease in size, 1.52 and 0.14 (dp, r) for the 12.7 x 2 mm fraction to 1.75 and 0.17 for the 2 x 0.6 mm fractions respectively. The combined average of the two tests for the 12.7 x 0.6 mm fraction is 0.16 corresponding to 1.58 average dp (Table 11). Presence of high ash particles in the feed and fluctuation in the water feed rate to the jig during testing might hve caused deterioration in the separation efficiency. Batac jig results of four tests are compared with predicted performance from a Baum

jig model (Fig. 6). Tests 3 and 11 data are excluded due to segregation of high ash particles (Test 11) or fine particles (Test 3) in the raw coal bin that made the size and washability of their feed different from other tests. Batac jig performance has comparable results to the Baum jig predicted data (Fig. 6).

Water-Only-Washing Cyclone Performance

The two stage water-only cyclones (WOC) are set to separate at relatively low dp by using elongated chamber in the primary cyclone. The WOC produced relatively low ash clean coal ranging between 12.0 and 16.8% and acceptable reject with 45.1 to 55.7% ash for the 0.6 x 0.15 mm size range (Table 12). The 0.15 mm x 0 fraction is removed in a classifier cyclone (overflow product) and cleaned in a bank of Denver flotation cells.

Froth Flotation Performance

Pilot plants tests (Table 13) produced lower ash in the froth than in bench scale flotation tests (Table 8). The lower yield and ash found in pilot plant tests as compared with bench scale tests are due to the mechanical difference between the two testing units. In pilot plant or industrial scale flotation, there is less thorough agitation and air bubbles per unit area than in the bench flotation. The result is a selective separation with lower ash and recovery than in the bench scale test. No evidence of extensive surface oxidation was observed in coal floatability both in bench and pilot plant tests which produced firm froth with relatively good recovery but at relatively high rates of reagents consumption. However, as seen in Table 13, reducing reagent addition to produce low ash froth resulted in an unacceptable low ash in tailings. Increased reagents addition (close to amounts used in Test 8, Table 8) and increased retention time would produce acceptable results comparable to the one shown in Test 3 of Table 13. No accurate rate of reagent addition is available due to changes in fine (0.15 mm x 0) feed rate from test to test, however, the optimum ratio of kerosene to MIBC is 6:1.

PROPOSED FLOWSHEET

As indicated earlier, crushing the coarse refuse is beneficial before washing to improve recovery as a result of liberating coal particles from middlings. The schematic flowsheet in Fig. 10 is suggested with crushing the feed to 10 mm top size. The flowsheet includes density separation by Batac jig or HMC for the plus 0.5 mm fraction. The fine cleaning section for the minus 0.5 mm fraction includes water-only cyclone and froth flotation similar to the existing cells in the Elkview preparation plant.

Performance predictions for the HMC and Baum jig for the plus 0.6 mm fraction are shown in Fig. 11. As can be expected the HMC shows higher yield than the jig at 27900 kJ/kg (20.8% ash) in the clean coal. The selection of a density separation unit to clean coarse refuse does not only depend on performance alone but also on capital and operating costs, particularly in relation to recovering saleable coal from refuse material. The decision on whether a Batac jig or HMC is selected can only be made after complete economic evaluation is done.

Assuming a Batac jig is selected. The overall performance of the proposed flowsheet is to produce clean coal comparable in heat value to Foothills thermal coal with approximately 27900 kJ/kg (or 20.8% ash). Based on projection from pilot plant results of Batac jig, WOC and froth flotation: at 27900 kJ/kg a recovery of 39.7% by mass is expected which corresponds to 63.0% thermal recovery.

CONCLUSIONS AND RECOMMENDATIONS

1. Significant improvement in coarse refuse washability is obtained by crushing the coarse refuse from 100 mm to 12.7 mm top size. The improvement is reflected in the increase in recovery from 32.5 to 44% by mass at 20.8% ash (equivalent to 27912 kJ/kg) which is similar in heat value to Foothills thermal coal.

2. Batac jig testing for the 12.7 x 0.6 mm shows slightly better performance than can be expected from a Baum jig model. Overall average results indicate a probable error of 0.16 at 1.58 cutpoint. Both the

water-only cyclone and froth flotation performed well and resulted in clean coal with 13.9% ash for the water-only cyclone (0.6 x 0.15 mm) and 9.5 to 17.6% ash for the froth flotation (0.15 mm x 0).

3. Based on the coal characteristics and pilot plant testing, an outline of a flowsheet is proposed. The flowsheet includes either a heavy medium cyclone or a Batac jig (depending on further economic evaluation) for the plus 0.5 mm, two stage water-only cyclone for the 0.5 x 0.15 mm, and froth flotation for the minus 0.15 mm. Based on projections from pilot plant test results the proposed flowsheet is expected to produce clean coal with 27900 kJ/kg (approx. 20.8% ash) with a recovery of 39.7% by mass and a corresponding 63.0% thermal recovery.

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Table 1 - Analysis of Westar Coal coarse refuse bulk shipment

	As Rec'd	Dry (db)
Moisture (%)	0.6	-
Ash (%)	49.3	49.4
kJ/kg (cal)	16346	16306

Table 2 - Size analysis of coarse refuse fed to the pilot plant

Particle Size mm	Elementary			Cumulative	
	Mass %	Ash %	kJ/kg	Mass%	Ash %
plus 25	1.60	64.82	10042	1.60	64.82
25 - 12.7	5.51	65.13	9916	7.11	65.06
12.7 - 6.3	25.32	50.55	15839	32.43	53.73
6.3 - 2.0	21.88	47.73	16984	54.31	51.31
2.0 - 0.6	26.10	43.36	18759	80.41	48.73
0.6 - 0.15	13.00	37.12	21294	93.41	47.12
0.15 - 0.074	1.90	35.18	22082	95.31	46.88
0.074 - 0.044	1.80	32.02	23365	97.11	46.60
minus 0.044	2.89	34.07	22533	100.00	46.24
TOTAL	100.00	46.24	17589	-	-

Mean particle size = 3.03 mm.

Table 3 - Washing characteristics of Westar coarse refuse 100 X 0.6 mm (92.7% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	0.12	3.00	35153	0.12	3.00	35153	100.00	50.53	15848
1.30 - 1.35	1.45	6.59	33695	1.57	6.32	33807	99.88	50.58	15825
1.35 - 1.40	3.17	11.74	31603	4.74	9.94	32333	98.43	51.23	15562
1.40 - 1.45	6.99	14.75	30381	11.73	12.81	31170	95.26	52.55	15028
1.45 - 1.50	8.49	21.19	27765	20.22	16.33	29740	88.27	55.54	13812
1.50 - 1.55	6.85	26.13	25758	27.07	18.81	28732	79.78	59.19	12327
1.55 - 1.60	6.49	31.77	23467	33.56	21.31	27714	72.93	62.30	11066
1.60 - 1.70	8.98	37.59	21103	42.54	24.75	26318	66.44	65.28	9854
1.70 - 1.80	7.00	47.77	16968	49.54	28.00	24997	57.46	69.61	8096
1.80 - Sink	50.46	72.64	6866	100.00	50.53	15848	50.46	72.64	6866

Table 4 - Washing characteristics of Westar coarse refuse 0.6 x 0.25 mm (5.3% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	9.50	3.10	35113	9.50	3.10	35113	100.00	35.83	21816
1.30 - 1.35	6.40	5.10	34300	15.90	3.91	34786	90.50	39.27	20420
1.35 - 1.40	9.00	7.80	33204	24.90	5.31	34214	84.10	41.87	19364
1.40 - 1.45	10.60	11.40	31741	35.50	7.13	33476	75.10	45.95	17706
1.45 - 1.50	8.30	16.50	29670	43.80	8.91	32754	64.50	51.63	15399
1.50 - 1.55	5.80	20.90	27882	49.60	10.31	32185	56.20	56.82	13291
1.55 - 1.60	4.40	27.30	25283	54.00	11.69	31622	50.40	60.95	11612
1.60 - 1.70	6.90	33.20	22886	60.90	14.13	30633	46.00	64.17	10305
1.70 - 1.80	4.90	41.30	19596	65.80	16.15	29811	39.10	69.64	8084
1.80 - Sink	34.20	73.70	6435	100.00	35.83	21816	34.20	73.70	6435

Table 5 - Washing characteristics of Westar coarse refuse 0.25 mm x 0 (2.0% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	12.40	3.10	35113	12.40	3.10	35113	100.00	30.97	23791
1.30 - 1.40	11.70	5.70	34057	24.10	4.36	34600	87.60	34.92	22188
1.40 - 1.50	20.70	10.30	32188	44.80	7.11	33486	75.90	39.42	20359
1.50 - 1.60	14.10	17.20	29385	58.90	9.52	32504	55.20	50.34	15923
1.60 - 1.70	8.30	25.80	25892	67.20	11.53	31687	41.10	61.71	11304
1.70 - Sink	32.80	70.80	7613	100.00	30.97	23791	32.80	70.80	7613

Table 6 - Washing characteristics of Westar refuse fed to pilot plant 12.7 x 0.6 mm (80.41% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	3.87	4.59	34508	3.87	4.59	34508	100.00	48.79	16552
1.30 - 1.35	3.58	7.96	33139	7.45	6.21	33850	96.13	50.57	15830
1.35 - 1.40	6.91	11.45	31721	14.36	8.73	32835	92.55	52.22	15160
1.40 - 1.45	7.39	17.47	29276	21.75	11.70	31619	85.64	55.51	12824
1.45 - 1.50	5.12	22.05	27415	26.87	13.67	30818	78.25	59.10	12364
1.50 - 1.60	10.08	29.09	23556	36.95	17.88	29110	73.13	61.70	11311
1.60 - 1.80	16.77	41.19	19641	53.72	25.16	26154	63.05	66.91	9193
1.80 - 2.00	10.73	55.52	13820	64.45	30.21	24100	46.28	76.23	5407
2.00 - 2.17	5.11	66.40	9400	69.56	32.87	23020	35.55	82.48	2868
2.17 - Sink	30.44	85.18	1772	100.00	48.79	16552	30.44	85.18	1772

Table 7 - Washing characteristics of Westar refuse fed to pilot plant 0.6 x 0.15 mm (13.0% of total)

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	1.60	3.02	35145	1.60	3.02	35145	100.00	37.26	21238
1.30 - 1.35	8.60	4.12	34698	10.20	3.95	34769	98.40	37.81	21012
1.35 - 1.40	15.59	6.74	33634	25.79	5.64	34083	89.80	41.04	19701
1.40 - 1.45	9.51	13.27	30982	35.30	7.69	33247	74.21	48.25	16774
1.45 - 1.50	7.31	19.20	28573	42.61	9.67	32445	64.70	53.39	14686
1.50 - 1.60	9.81	26.83	25474	52.42	12.88	31141	57.39	57.74	12917
1.60 - 1.80	10.80	38.93	20559	63.22	17.33	29333	47.58	64.12	10328
1.80 - 2.00	9.50	52.31	15124	72.72	21.90	27477	36.78	71.51	7324
2.00 - 2.17	5.10	66.50	9360	77.82	24.82	26289	27.28	78.20	4607
2.17 - Sink	22.18	80.89	3514	100.00	37.26	21238	22.18	80.89	3514

Table 8 - Bench scale flotation tests

Test No.	Froth		Tailings		Recon. Feed Ash %	Kerosene :MIBC	Reagent rate Kg/tonne
	Mass %	Ash %	Mass %	Ash %			
1	68.40	23.50	31.60	62.82	35.93	3:1	1.8
2	82.67	29.20	17.33	74.25	37.01	3:1	3.6
3	41.71	19.66	58.29	50.56	37.67	4:1	1.8
4	77.51	27.64	22.49	71.00	37.39	4:1	3.6
5	40.94	20.10	59.06	49.45	37.43	5:1	1.8
6	38.97	22.92	61.03	57.41	43.97	5:1	3.6
7	45.67	21.56	54.33	49.34	36.65	6:1	1.8
8	70.85	24.43	29.15	63.55	35.83	6:1	3.6
9	66.90	24.79	33.10	60.67	36.67	4:1*	1.8
10	86.63	30.50	13.37	75.56	36.52	4:1*	3.6

* Natural pine oil instead of MIBC.

Table 9 - Summary of products analyses - washing tests (ash contents on dry basis)

Test No.	Per Cent	Raw Coal	Clean Coal			Final Products		
			Batac Jig	Water-only-Cyclone	Froth Flotation	Clean Coal	Coarse Reject	Fine Reject
3	Ash	51.27	25.57	16.79	17.60	22.55	63.57	53.91
	Moisture	-	-	-	78.85	6.55	-	7.28
	Yield	100.00	-	-	-	-	-	-
6	Ash	47.96	18.07	12.96	14.17	17.22	63.13	47.14
	Moisture	1.66	-	-	89.29	5.35	20.04	8.28
	Yield	100.00	-	-	-	-	-	-
6A	Ash	45.68	20.79	13.79	12.87	18.84	62.69	42.44
	Moisture	1.18	-	84.50	73.55	6.31	19.99	7.51
	Yield	100.00	-	-	-	-	-	-
7A	Ash	47.36	20.38	14.57	11.12	17.67	61.90	42.16
	Moisture	1.33	-	84.58	83.98	7.52	21.87	9.22
	Yield	100.00	-	-	-	21.51	59.28	19.21
8	Ash	47.40	21.50	11.96	9.47	19.49	64.52	36.54
	Moisture	1.33	-	88.38	81.79	5.83	18.98	8.02
	Yield	100.00	-	-	-	23.42	57.77	18.81
11	Ash	49.06	22.37	12.84	9.65	18.51	64.90	37.95
	Moisture	2.76	-	91.52	78.49	6.46	20.87	6.76
	Yield	100.00	-	-	-	10.73	74.33	14.94

Table 10 - Thermal recovery in relation to cutpoint

Test	Raw Coal		Clean Coal			
	Mass kg	Ash %	Yield %	Ash %	dp (Batac Jig)	Thermal Recovery %
3	-	51.27	-	22.55	-	-
6	1630	47.96		17.22	1.45	-
6A	2948	45.68	-	18.84	-	-
7A	3175	47.36	21.51	17.67	1.57	36.68
8	3340	47.40	23.42	19.49	1.60	38.93
11	2878	49.06	-	18.51	-	-
Total	13971	47.44	22.49	-	-	37.83

Table 11 - Summary of Batac jig performance

Test No.	Cutpoint (dp)			Performance					
	12.7 x 2 mm	2 x 0.6 mm	12.7 x 0.6 mm	12.7 x 2 mm		2 x 0.6 mm		12.7 x 0.6 mm	
				r*	Error Area	r*	Error Area	r	Error Area
7A	1.49	1.71	1.57	0.14	86	0.16	105	0.16	96
8	1.54	1.79	1.60	0.14	86	0.18	104	0.17	99
Average	1.52	1.75	1.58	0.14	86	0.17	105	0.16	98

*Probable error

Table 12 - Water-only cyclone (elongated chamber) washing results (0.6 x 0.15 mm)

Test	% Ash			Yield%
	Raw Coal	Clean Coal	Reject	
3	$d_{41.0}$	16.79	55.68	37.8
8	-	11.96	45.48	38.6
11	-	12.84	45.09	41.6
Average	-	13.86	48.75	39.33

*Elongated chamber was used to increase vortex finder clearance and lower cyclone dp.

Table 13 - Froth flotation washing results

Test No.	3		6		6A		7A		8		11	
Product	Mass %	Ash %	Mass %	Ash %	Mass %	Ash %	Mass %	Ash %	Mass %	Ash %	Mass %	Ash %
Froth	44.6	17.60	-	14.17	-	12.87	-	11.12	-	9.47	-	9.65
Tailings	55.4	46.92	-	-	-	33.58	-	28.36	-	26.15	-	26.32

Reagents addition rate in Test 3 was 3.6 kg/tonne (Kerosene (6): MIBC (1)) however, reagent rates decreased gradually from test 6 to 11 to achieve lower ash in froth.

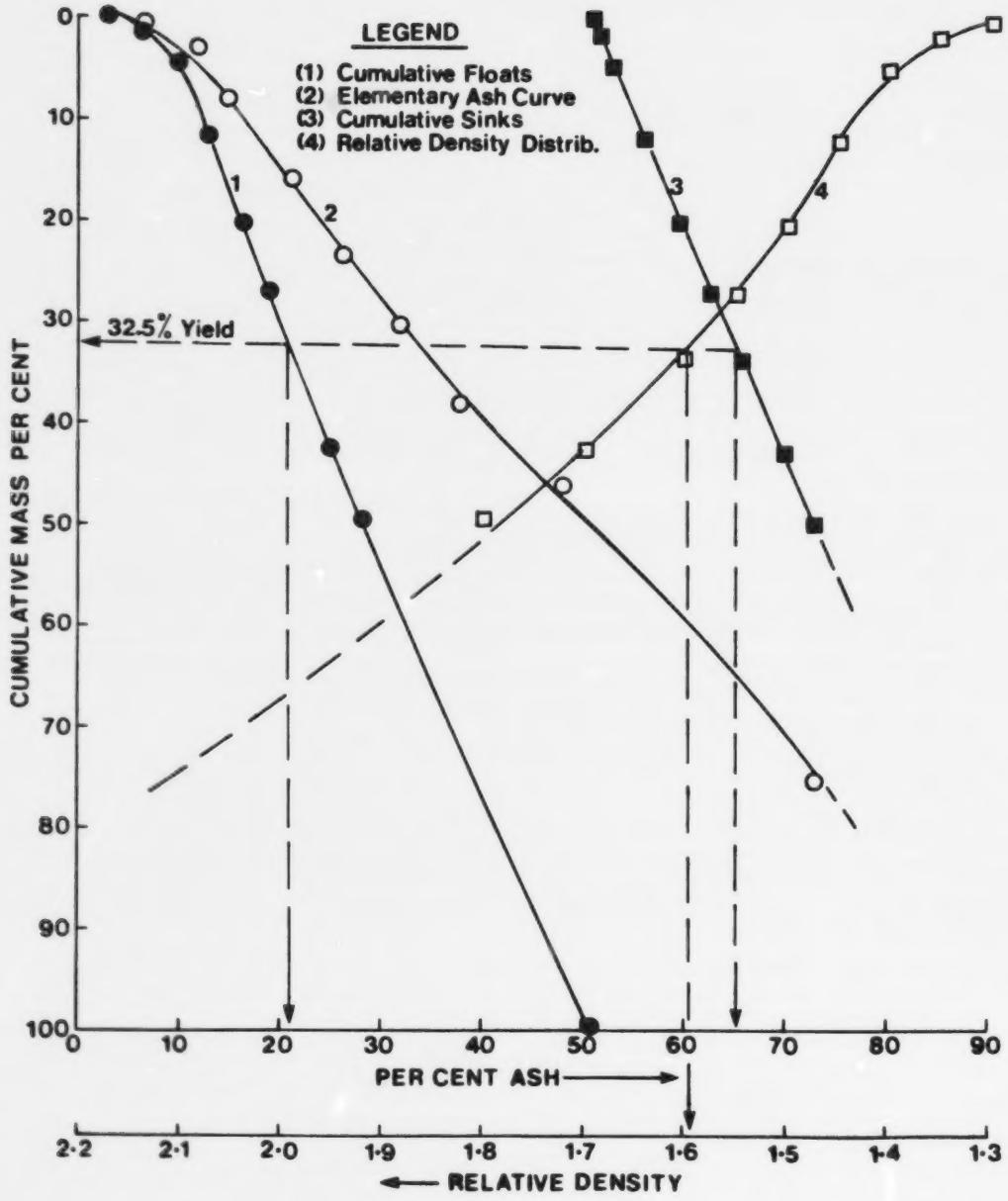

Fig. 1 - Washability curves: Westar refuse 100 x 0.6 mm (92.7% of total).

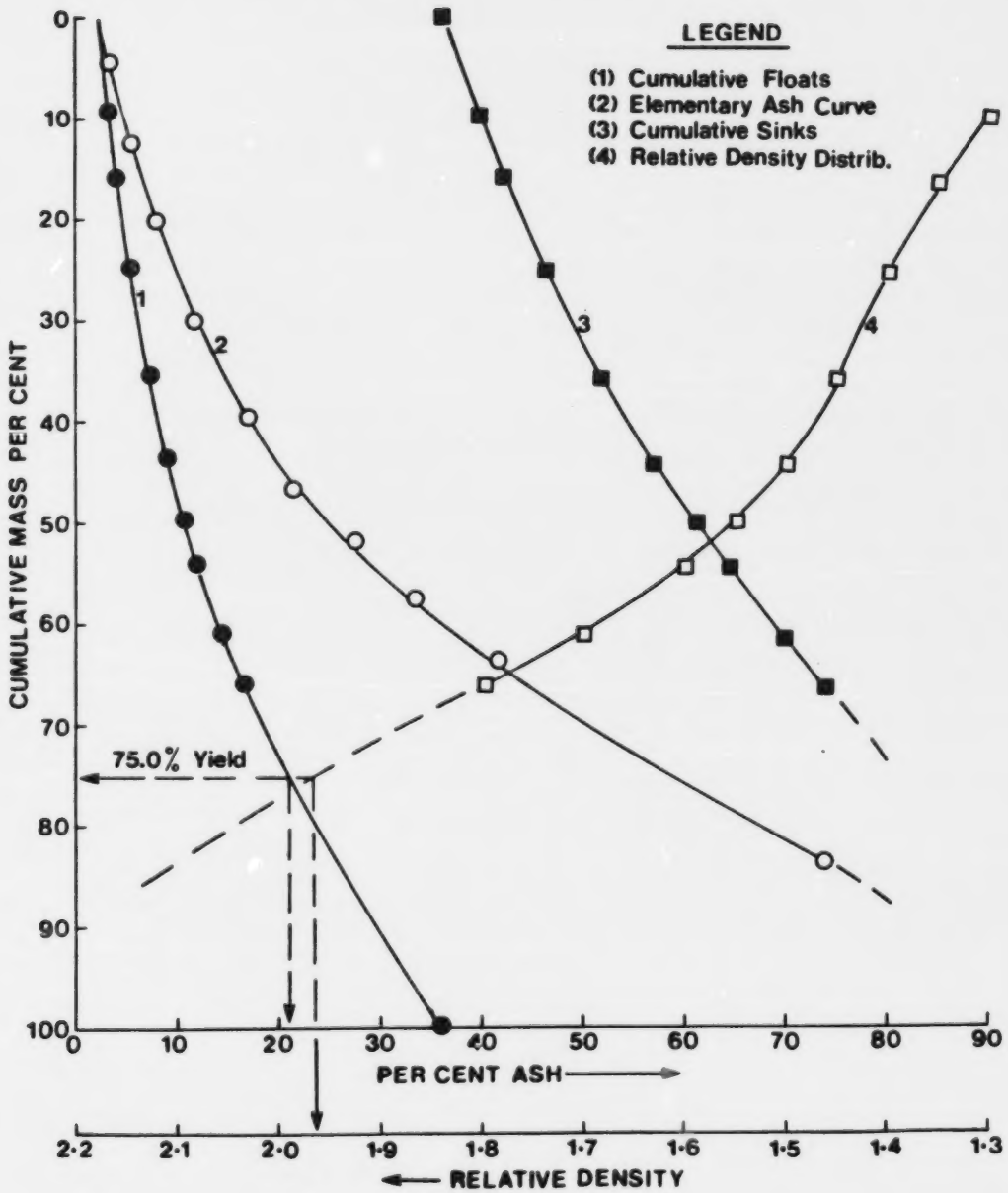

Fig. 2 - Washability curves: Westar refuse 0.6 x 0.25 mm (5.3% of total).

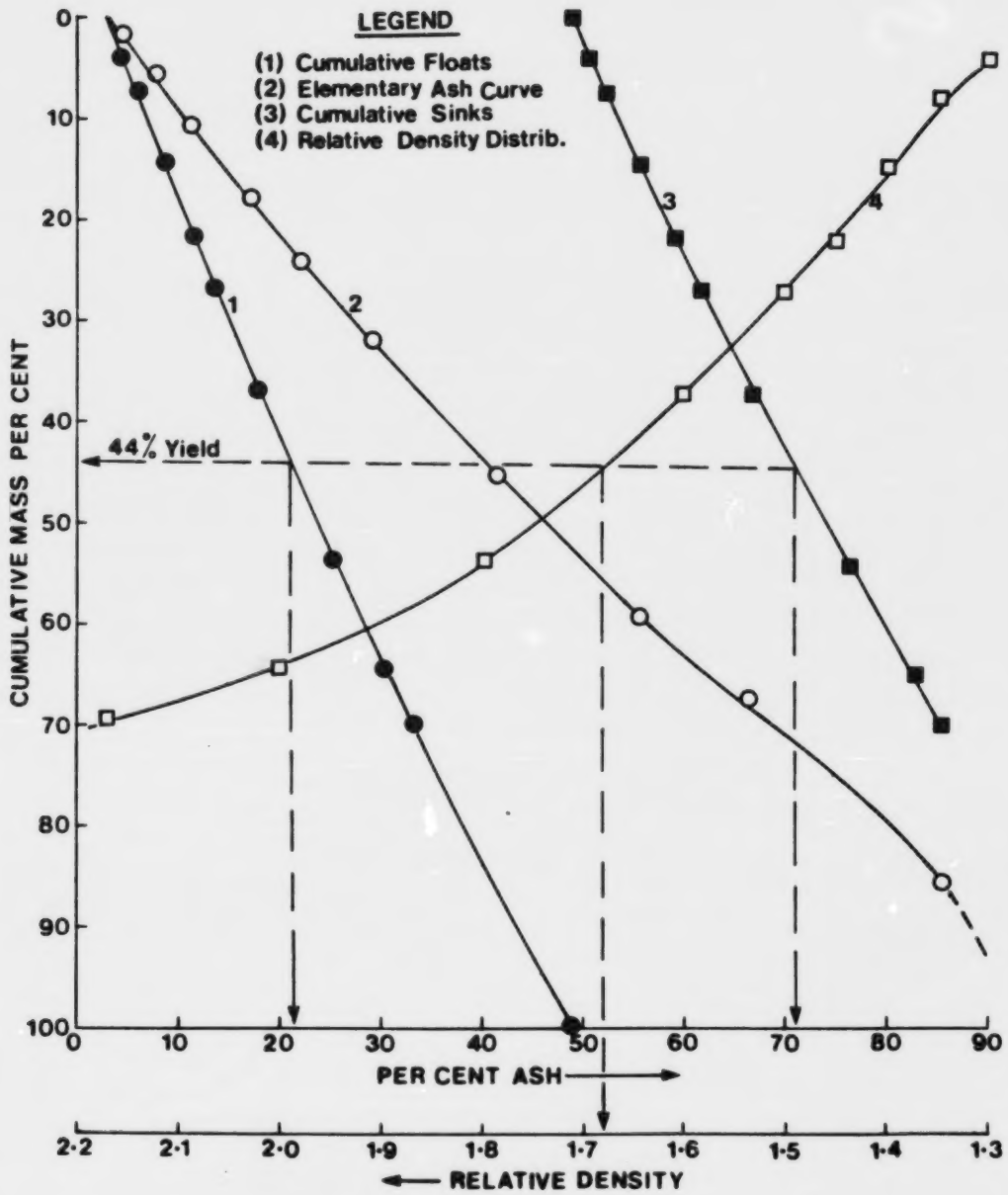

Fig. 3 - Washability curves: Westar crushed refuse 12.5 x 0.6 mm (80.41% of total).

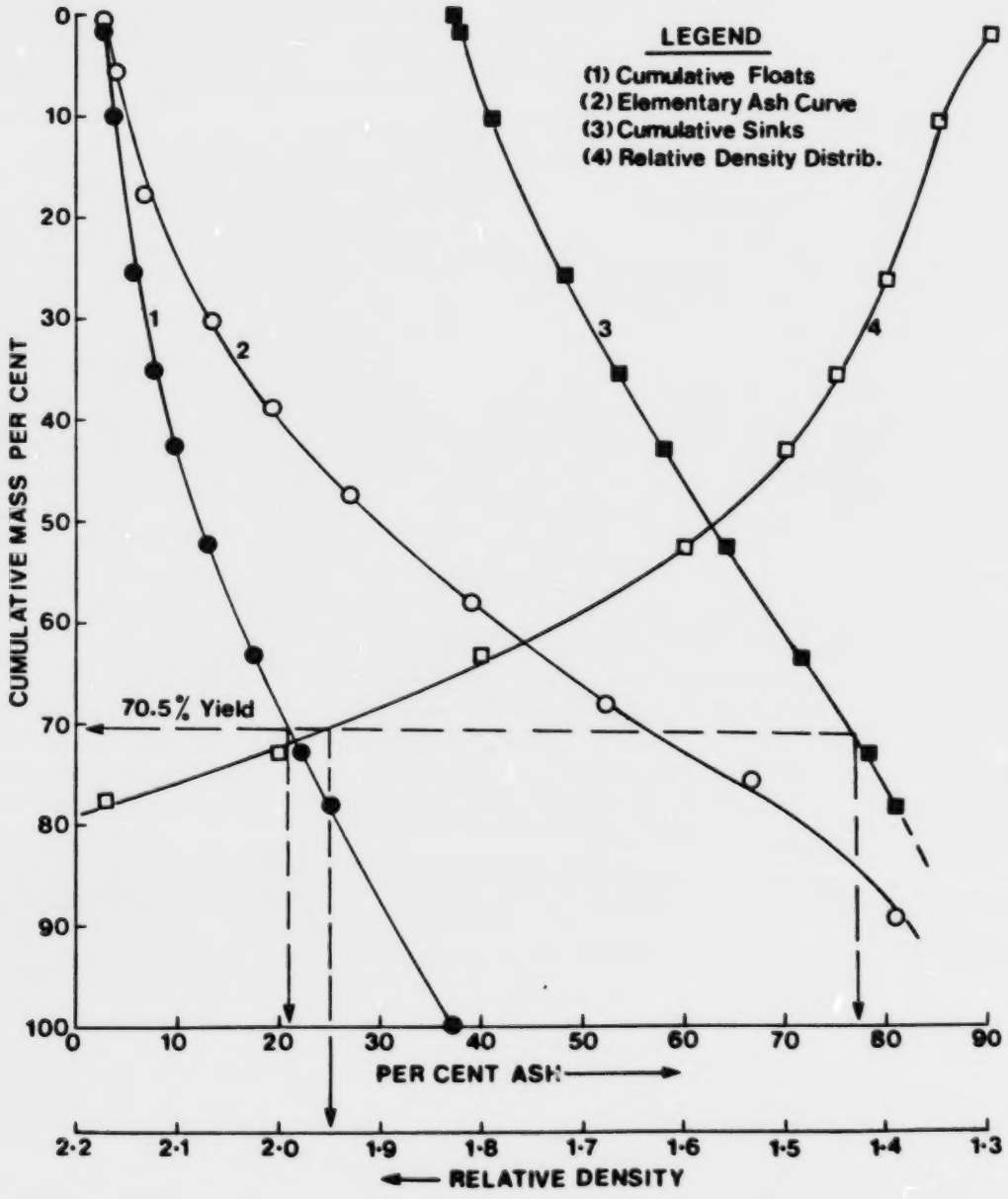

Fig. 4 - Washability curves: Westar crushed refuse 0.6 x 0.15 mm (13.0% of total).

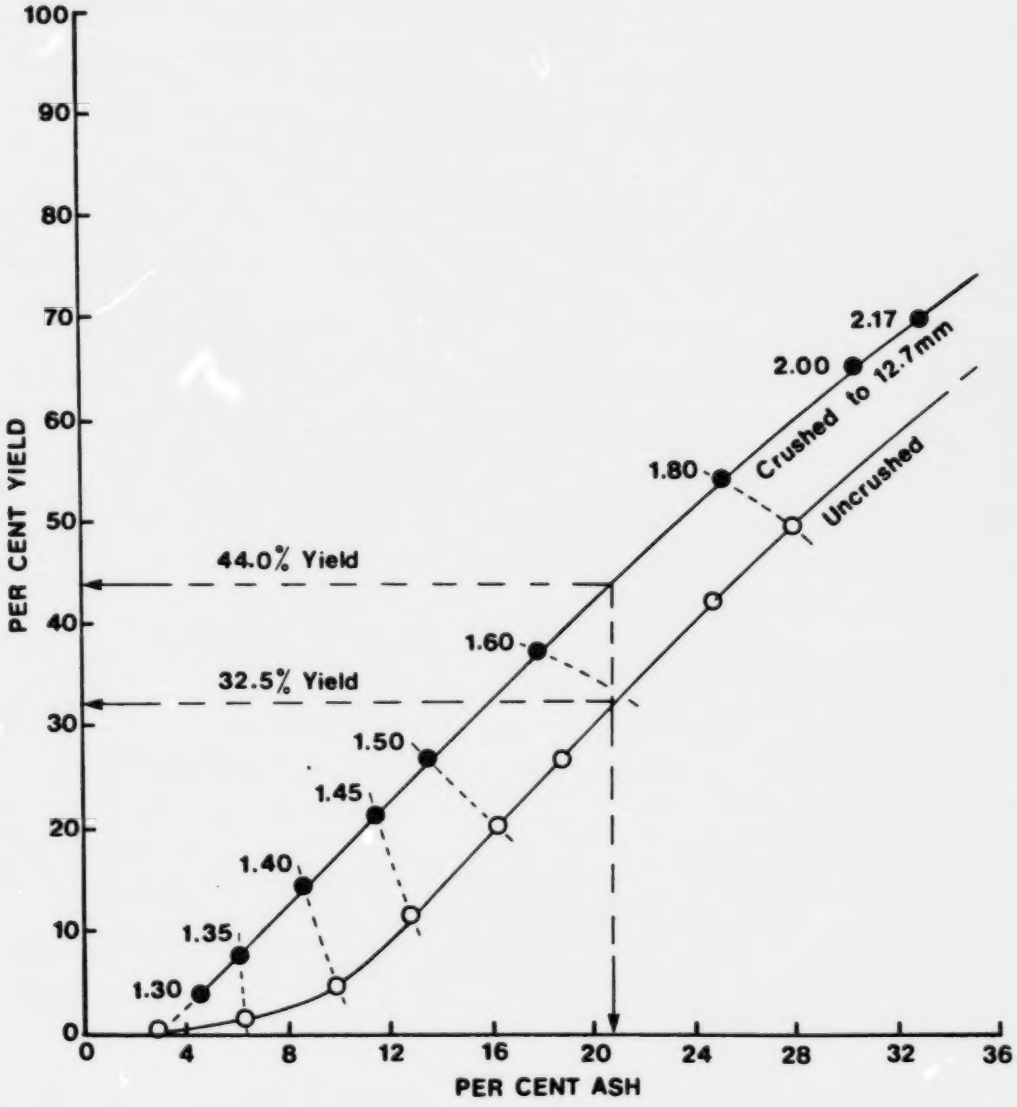

Fig. 5 - Effect of crushing on coal washability.

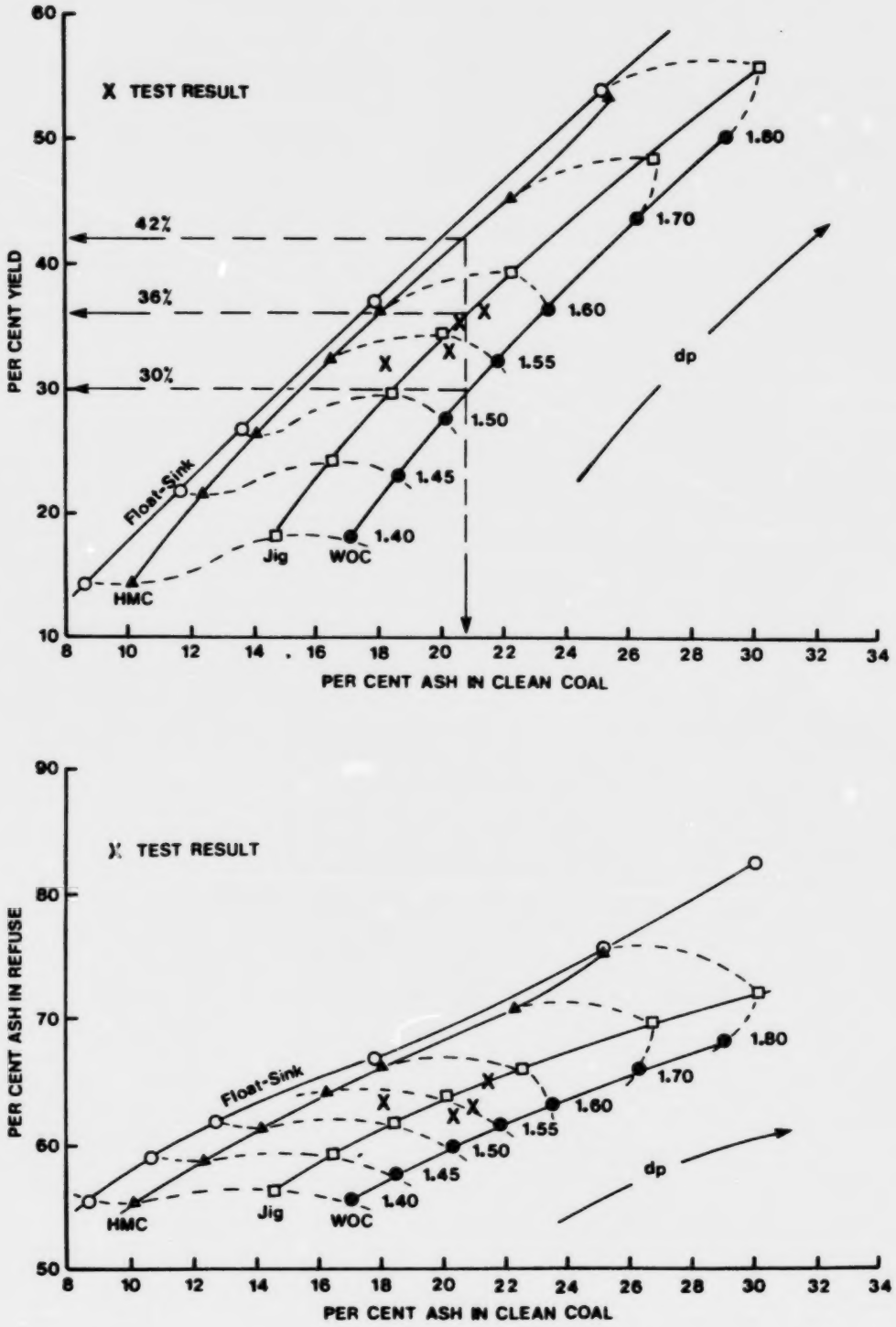

Fig. 6 - Performance evaluation prediction (12.7 x 0.6 mm).

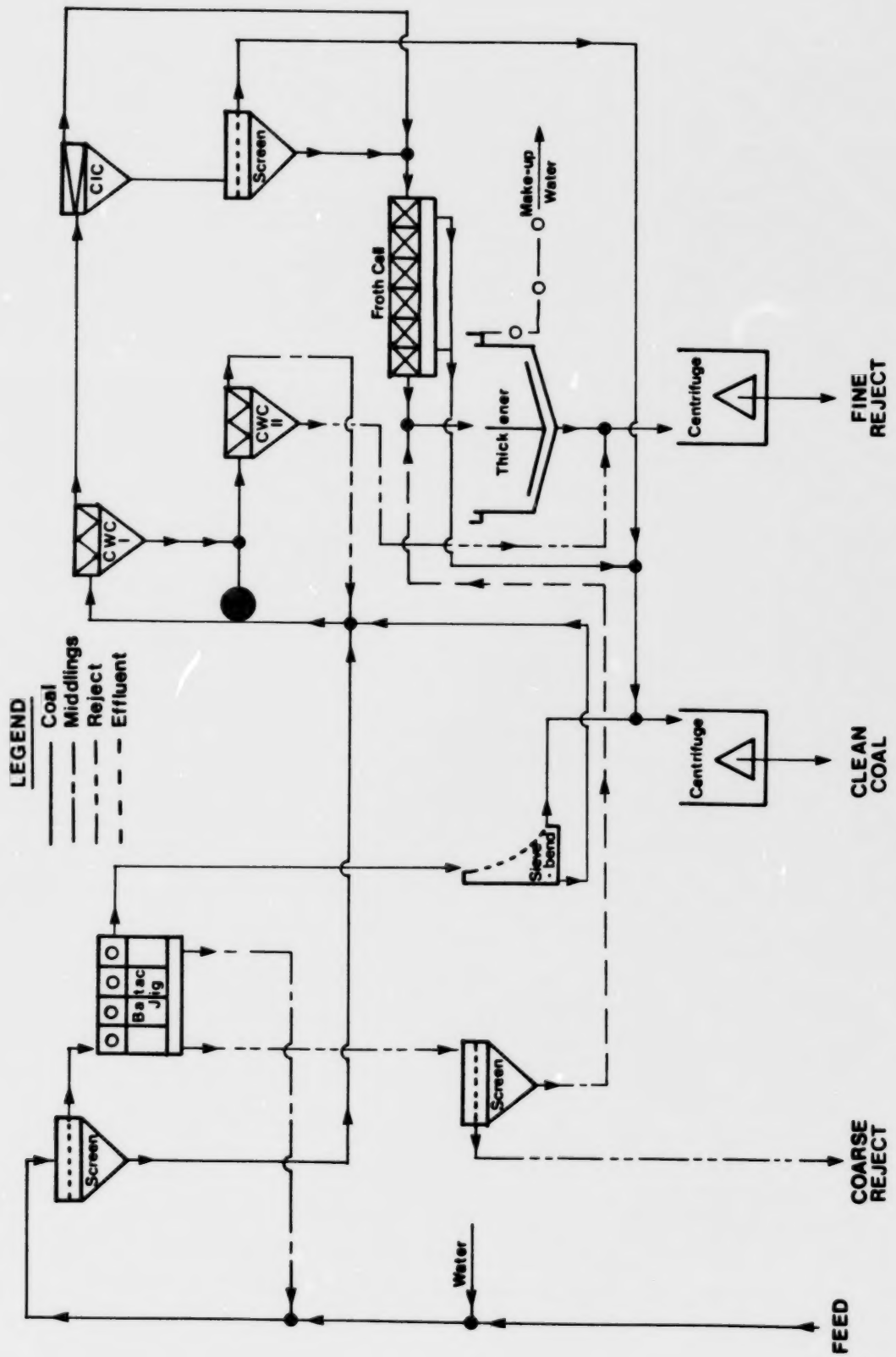

Fig. 7 - Simplified flowsheet of the pilot plant.

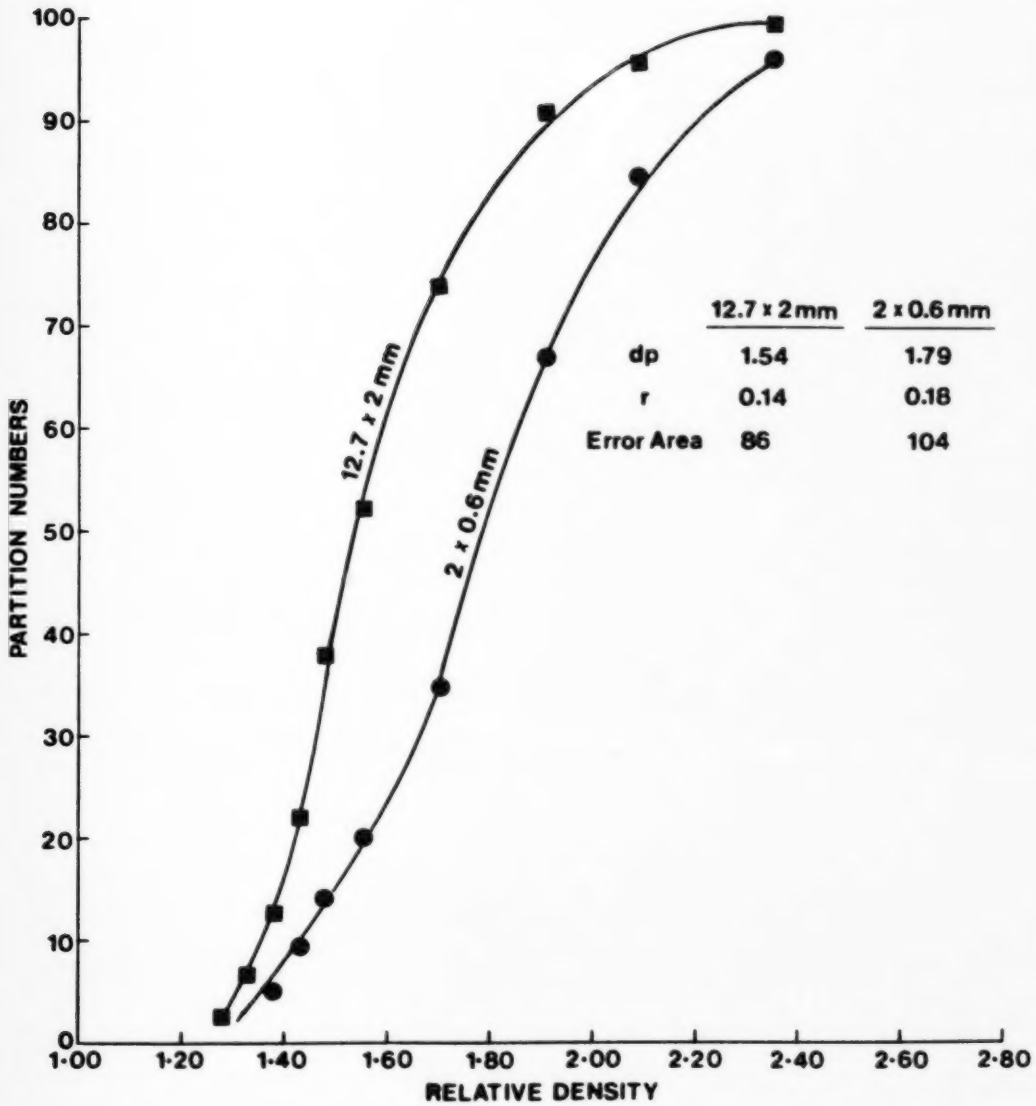

Fig. 8 - Error curves for Batac jig (test 8).

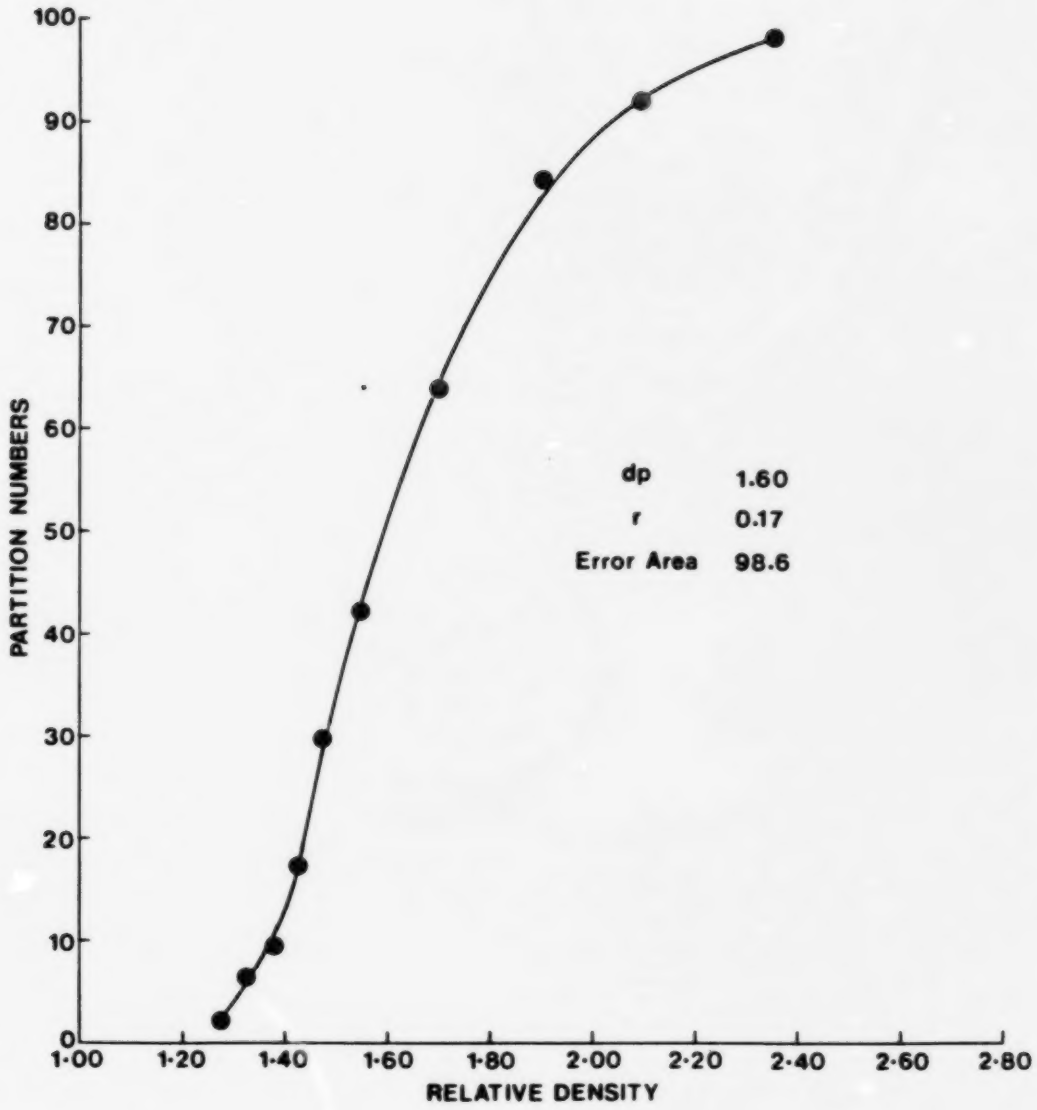

Fig. 9 - Error curve for Batac jig 12.7 x 0.6 mm (test 8).

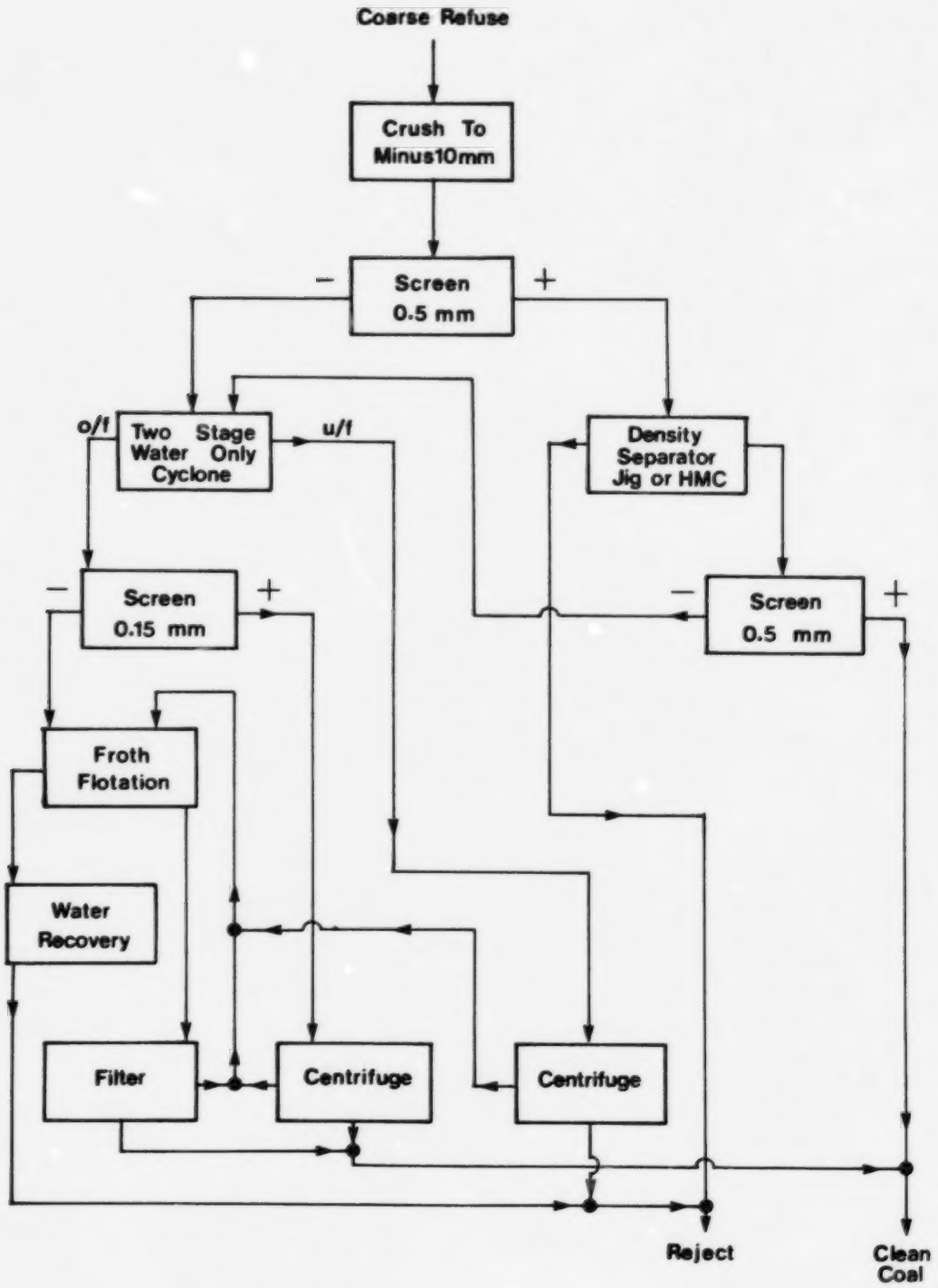

Fig. 10 - Schematic of proposed preparation plant - Westar coarse refuse.

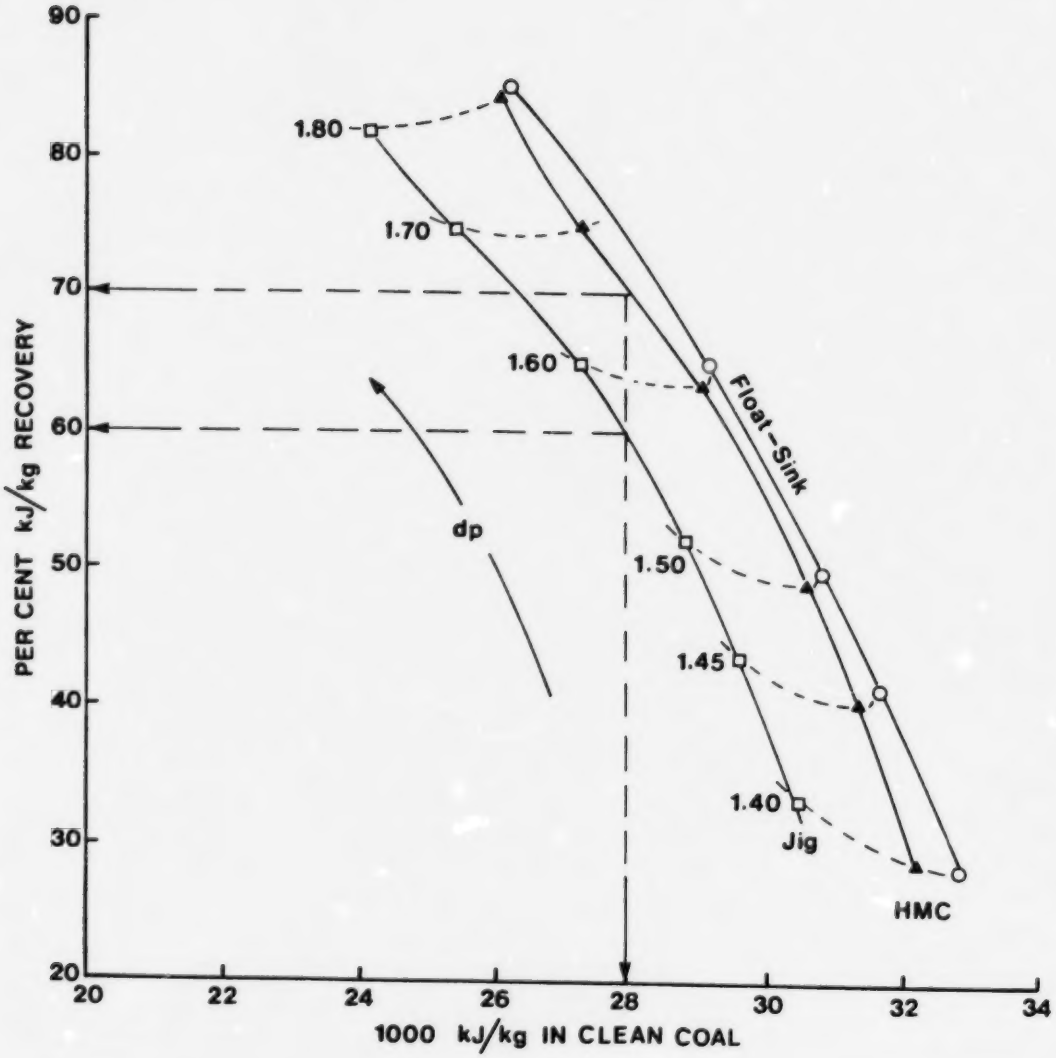

Fig. 11 - Thermal recovery predictions for the Batac jig and Heavy Medium Cyclone (HMC) - plus 0.6 mm.

APPENDIX A

WASHABILITY DATA AND ASH-kJ RELATIONSHIP

Table A-1 - Washing characteristics of Westar refuse 6.3 x 0.6mm

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	0.30	4.20	34666	0.30	4.20	34666	100.00	55.05	14009
1.30 - 1.35	1.50	7.80	33204	1.80	7.20	33447	99.70	55.21	13947
1.35 - 1.40	2.90	11.40	31741	4.70	9.79	32395	98.20	55.93	13652
1.40 - 1.45	8.20	15.40	30117	12.90	13.36	30947	95.30	57.29	13102
1.45 - 1.50	7.00	21.90	27476	19.90	16.36	29726	87.10	61.23	11500
1.50 - 1.55	5.10	26.90	25445	25.00	18.51	28853	80.10	64.67	10104
1.55 - 1.60	5.30	32.50	23171	30.30	20.96	27859	75.00	67.24	9061
1.60 - 1.70	8.10	39.40	20368	38.40	24.85	26279	69.70	69.88	7988
1.70 - 1.80	6.70	45.90	17727	45.10	27.98	25008	61.60	73.88	6360
1.80 - Sink	54.90	77.30	4973	100.00	55.05	14009	54.90	77.30	4973

Table A-2 - Washing characteristics of Westar refuse 0.6 mm x 0

Relative Density	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg	Mass %	Ash %	kJ/kg
Float - 1.30	11.00	3.00	35153	11.00	3.00	35153	100.00	33.71	22679
1.30 - 1.35	6.40	5.30	34219	17.40	3.85	34810	89.00	37.51	21137
1.35 - 1.40	5.60	7.10	33488	23.00	4.64	34488	82.60	40.00	20123
1.40 - 1.45	10.20	9.90	32351	33.20	6.25	33831	77.00	42.40	19151
1.45 - 1.50	8.20	12.60	31254	41.40	7.51	33321	66.80	47.36	17136
1.50 - 1.55	7.00	16.50	29670	48.40	8.81	32793	58.60	52.22	15160
1.55 - 1.60	6.20	25.70	25933	54.60	10.73	32014	51.60	57.07	13192
1.60 - 1.70	7.80	30.10	24145	62.40	13.15	31030	45.40	61.35	11452
1.70 - 1.80	7.50	48.70	16590	69.90	16.96	29481	37.60	67.83	8818
1.80 - Sink	30.10	72.60	6882	100.00	33.71	22679	30.10	72.60	6882

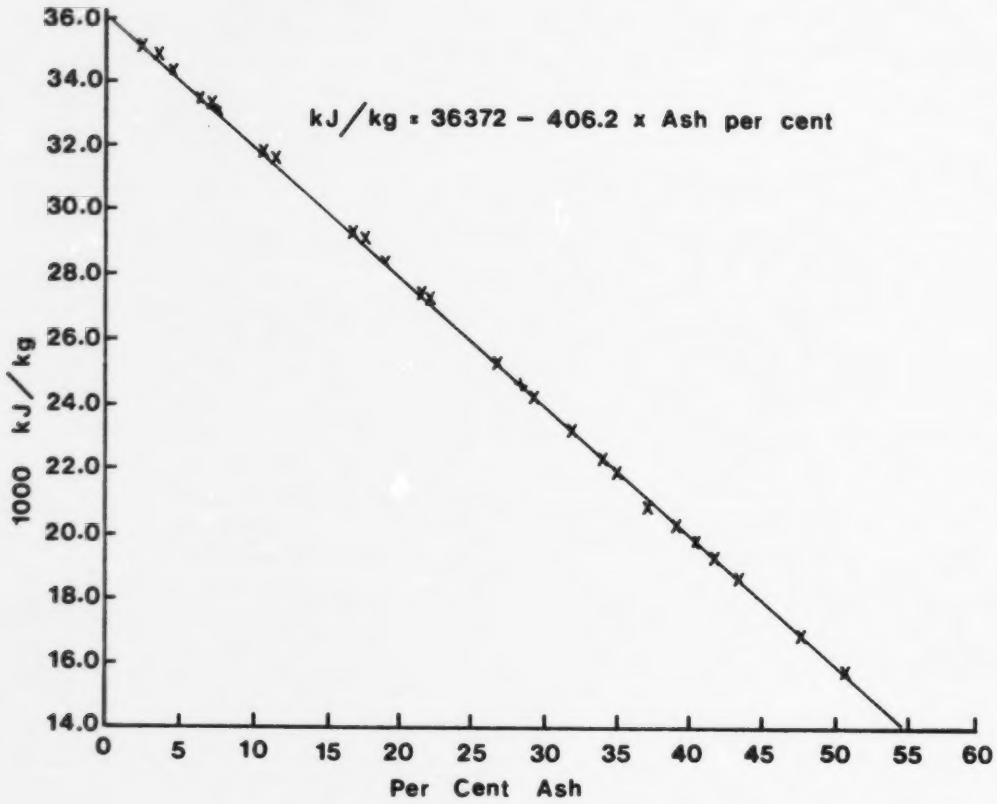

Fig. A-1 - Ash - kJ relationship - Westar Coal coarse refuse.